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Alternative Modeling Methods for Plasma-Based Rf Ion Sources

Seth A. Veitzer, Madhusudhan Kundrapu, Peter H. Stoltz, Kristian R.C. Beckwith

Tech-X Corporation, Boulder, CO, 80303 USA

Corresponding Author: Seth A. Veitzer, e-mail address: veitzer@txcorp.com

Rf-driven ion sources for accelerators and many industrial applications benefit from detailed numerical modeling and simulation of plasma characteristics. For instance, modeling of the SNS internal antenna H- source has indicated that a large plasma velocity is induced near bends in the antenna where structural failures are often observed. This could lead to improved designs and ion source performance based on simulation and modeling. However, there are significant separations of time and spatial scales inherent to Rf-driven plasma ion sources, which makes it difficult to model ion sources with explicit, kinetic Particle-In-Cell (PIC) simulation codes. In particular, if both electron and ion motions are to be explicitly modeled, then the simulation time step must be very small, and total simulation times must be large enough to capture the evolution of the plasma ions, as well as extending over many Rf periods. Additional physics processes, such as plasma chemistry and surface effects such as secondary electron emission increase the computational requirements in such a way that even fully parallel explicit PIC models can not be used.

One alternative method is to develop uid-based codes coupled with electromagnetics in order to model ion sources. Time-domain uid models can simulate plasma evolution, plasma chemistry, and surface physics models with reasonable computational resources by not explicitly resolving electron motions, which thereby leads to an increase in the time step. This is achieved by solving fluid motions coupled with electromagnetic using reduced-physics models, such as single-temperature magnetohydrodynamics (MHD), extended, gas dynamic, and Hall MHD, and two-fluid MHD models. We show recent results on modeling the internal antenna H- ion source for the Spallation Neutron Source (SNS) at Oak Ridge National Laboratory (ORNL) using the fluid plasma modeling code USim. We present simulation results demonstrating plasma evolution over many Rf periods for different plasma equation systems. We perform the calculations in parallel, on unstructured meshes, using finite-volume solvers in order to obtain 2nd-order accuracy.